Inventor Name: Girish Vsr CHIRUVOLU
Title of Invention: DOMAIN BASED CONGESTION MANAGEMENT
Serial No. 09/618,196 — Filing Date: July 19, 2000
SMZM&S Ref. No.: A8133
SMZM&S Tel. No.: (202) 293-7060

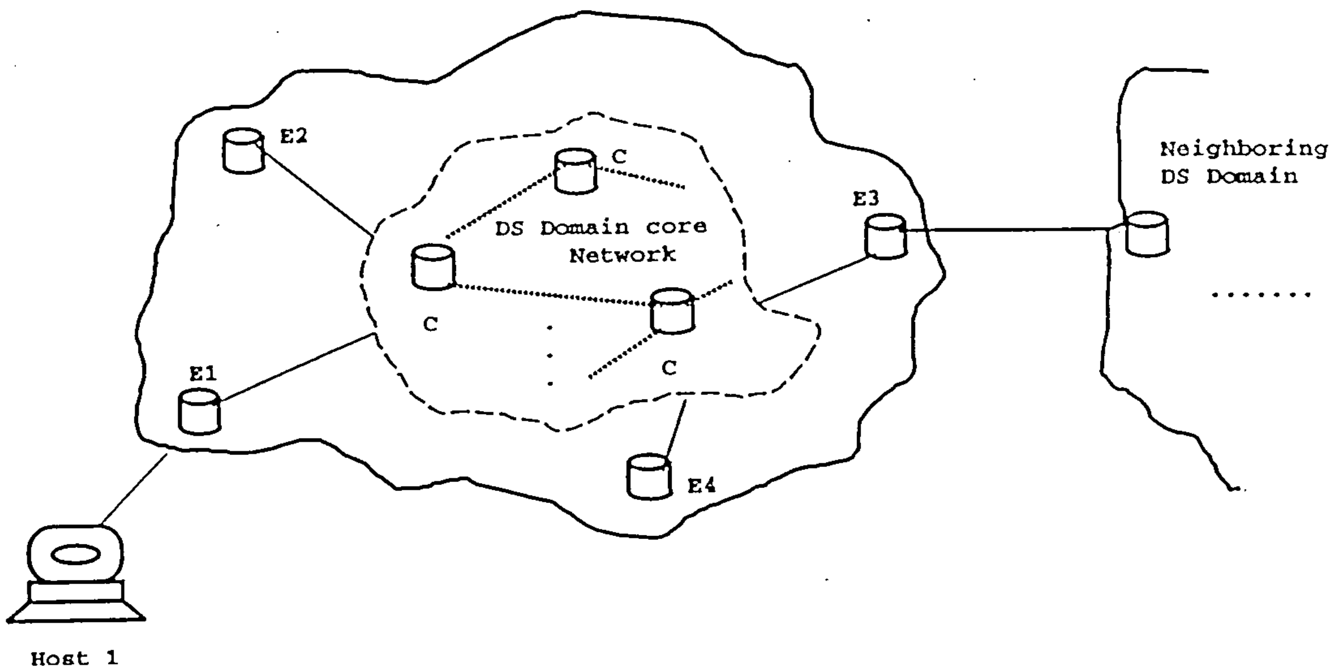


Fig. 1

DIFF-SERV DOMAIN

(PRIOR ART)

```
On every packet arrival

Calculate the average queue size based on exponential moving weighted average  100
if ( average queue size < minth) enqueue the packet  110

if ( minth < average queue size < FeedbackThreshold )
{

enqueue the packet,  120
mark the bits (bit1,bit2) for all outgoing packets queue with (1,0), if the bits are not
previously set as (1,1)  130
}
if ( FeedbackThreshold ≤ average·queue size < maxth)
{

drop or enqueue the packet with the probability as decided by RED  140
mark the bits (bit1,bit2) for all outgoing packets with (1,1)  150

}

if (average queue size > maxth) drop the incoming packets  160
```

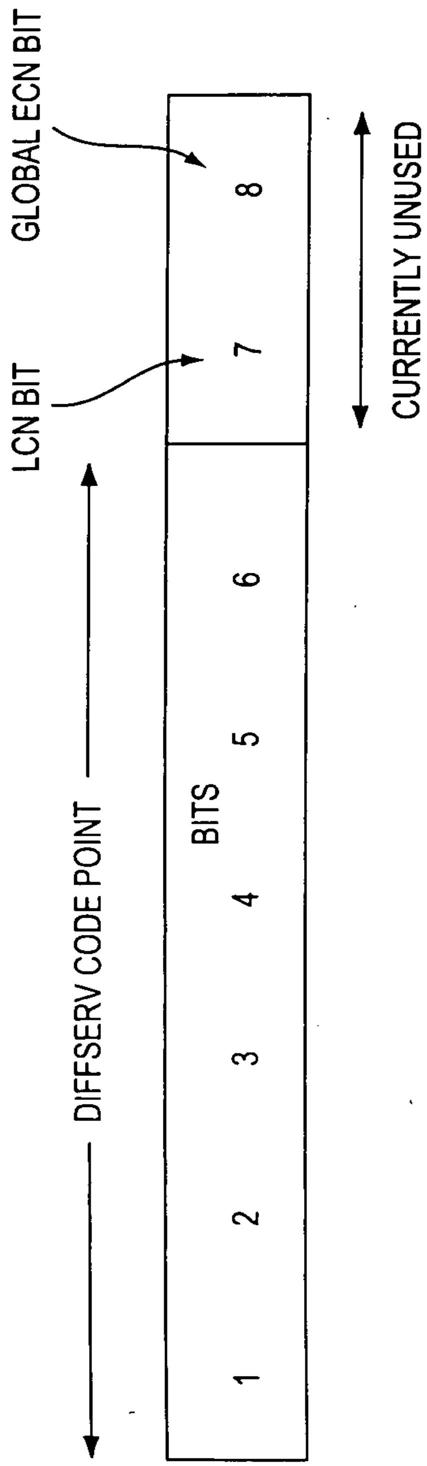
MODIFICATIONS TO THE RED ALGORITHM AT CORE NODES

FIG. 2

Bit1	Bit2	Inference at the egress node
0	0	No congestion detected so far up to this domain
0	1	No local congestion, but Congestion occurred in a prior domain
1	0	Local congestion occurred, but no packet loss phase
1	1	Local congestion occurred and in packet loss phase

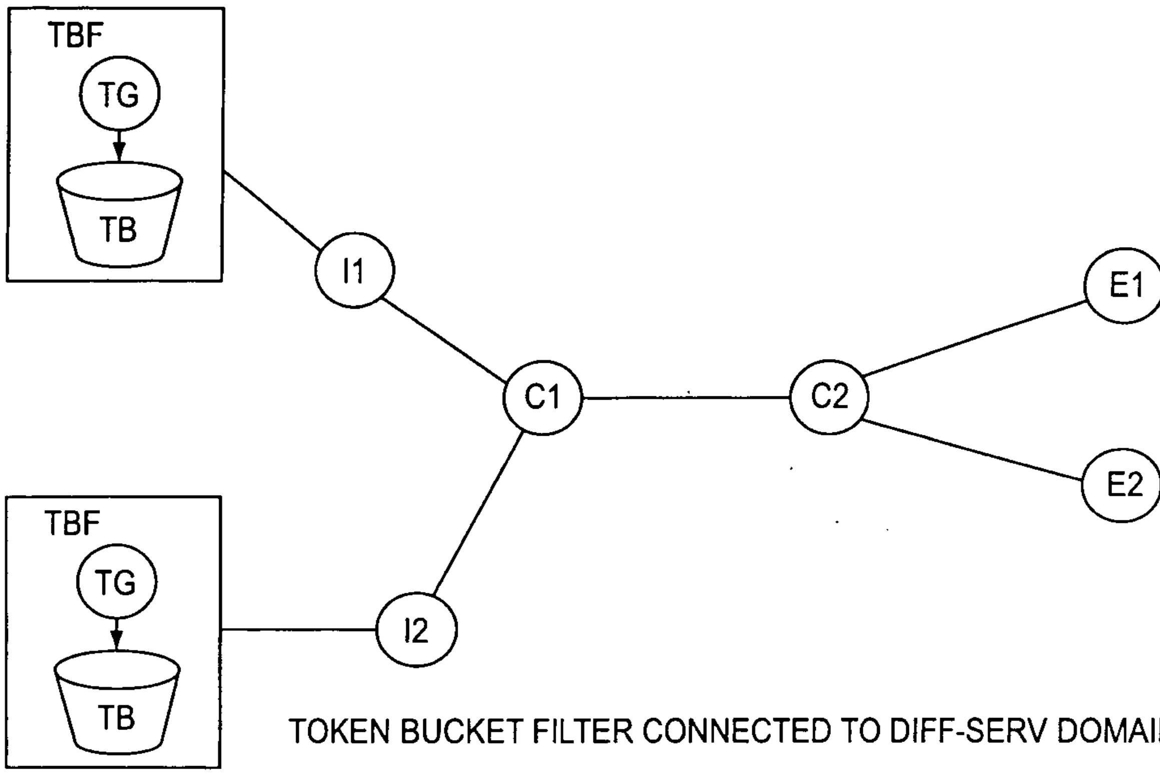
A SIMPLE TWO-BIT SCHEME FOR REPRESENTING LOCAL DOMAIN CONGESTION

FIG. 3



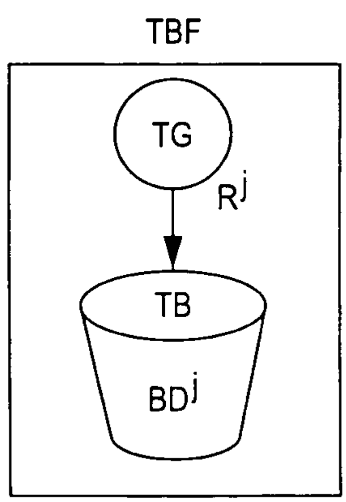
THE TOS/DSCP BYTE

FIG. 4



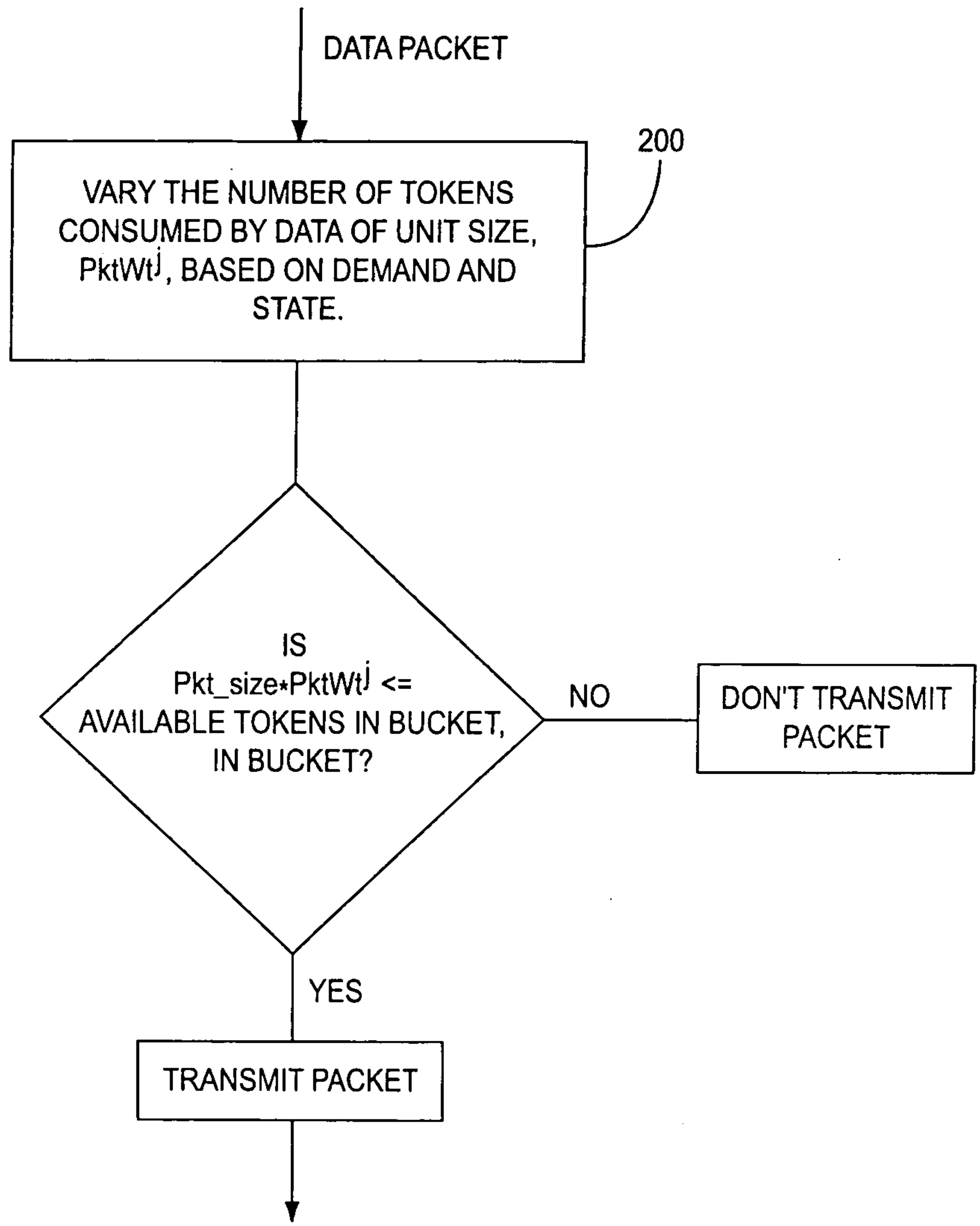
TOKEN BUCKET FILTER CONNECTED TO DIFF-SERV DOMAIN

FIG. 5A



COMPONENTS OF A TOKEN BUCKET FILTER

FIG. 5B



FLOWCHART FOR TBF-BASED RATE CONTROL METHOD

FIG. 6A

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Initialize: $PktWt_0^j \longleftarrow 1.0$

$PktWt^j$ is always within $[minPktWt^j, maxPktWt^j]$

MD is a monotonously decreasing function that takes a value (0,1)

MI is a monotonously increasing function that takes a positive value

j denotes the label corresponding to fixed route between a given pair of ingress/egress nodes

for every ith round trip time (between ingress and egress nodes)

<u>During congestion-free periods</u>

if(average TBF queue size at ingress node $\geq DemandThrsh^j$)

$PktWt_i^j \longleftarrow PktWt_{i-1}^j * MD(PktWt_{i-1}^j)$ 230

/* decrease the $PktWt^j$ during congestion free periods, based on demand at TBF */

else {

if $(PktWt_{i-1}^j > 1)$ $PktWt_i^j \longleftarrow max[1, PktWt_{i-1}^j * MD(PktWt_{i-1}^j)]$

if $(PktWt_{i-1}^j < 1)$ $PktWt_i^j \longleftarrow min[1, PktWt_{i-1}^j * MI(PktWt_{i-1}^j)]$ }

/* restore $PktWt^j$ close to 1.0 */

<u>At congestion notification time</u>

$$PktWt_i^j \longleftarrow \frac{(maxPktWt^j - 1)(1 - PktWt_{i-1}^j)}{(1 - minPktWt^j)} + 1 \qquad \text{if } PktWt_{i-1}^j < 1.$$

/* The smaller the $PktWt^j$ just before LCN, the bigger it will be during congestion period. A uniform mapping of $[minPktWt^j, 1)$ on to $(1, maxPktWt^j)$ intervals */ 250

<u>During congestion period</u>

$PktWt_i^j \longleftarrow PktWt_{i-1}^j * MI(PktWt_{i-1}^j)$ if $PktWt_{i-1}^j \neq 1$ 240

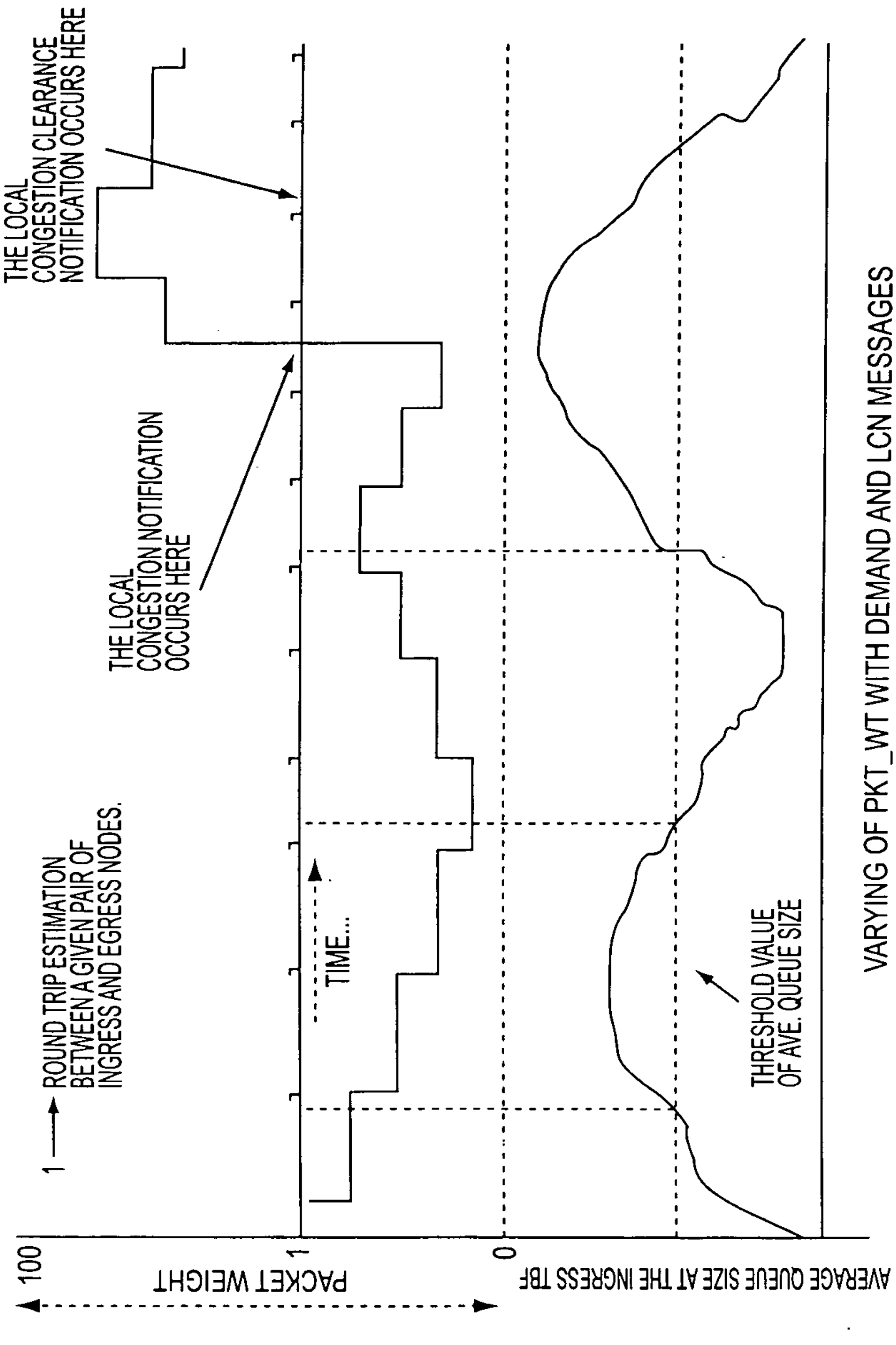
<u>On receipt of congestion clearance notification</u>

Select a random time less than RTT and,

$PktWt_i^j \longleftarrow PktWt_{i-1}^j * MD(PktWt_{i-1}^j)$ 220

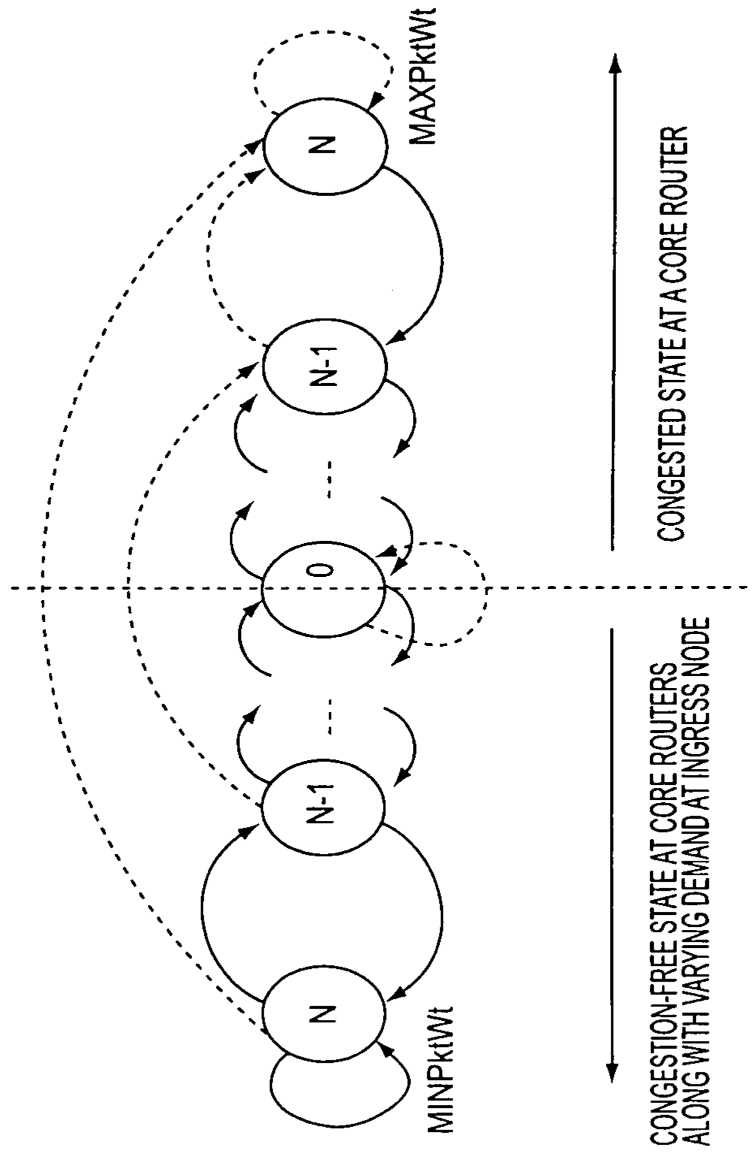
THE TBF-BASED CONGESTION MANAGEMENT ALGORITHM AT INGRESS NODES

FIG. 6B



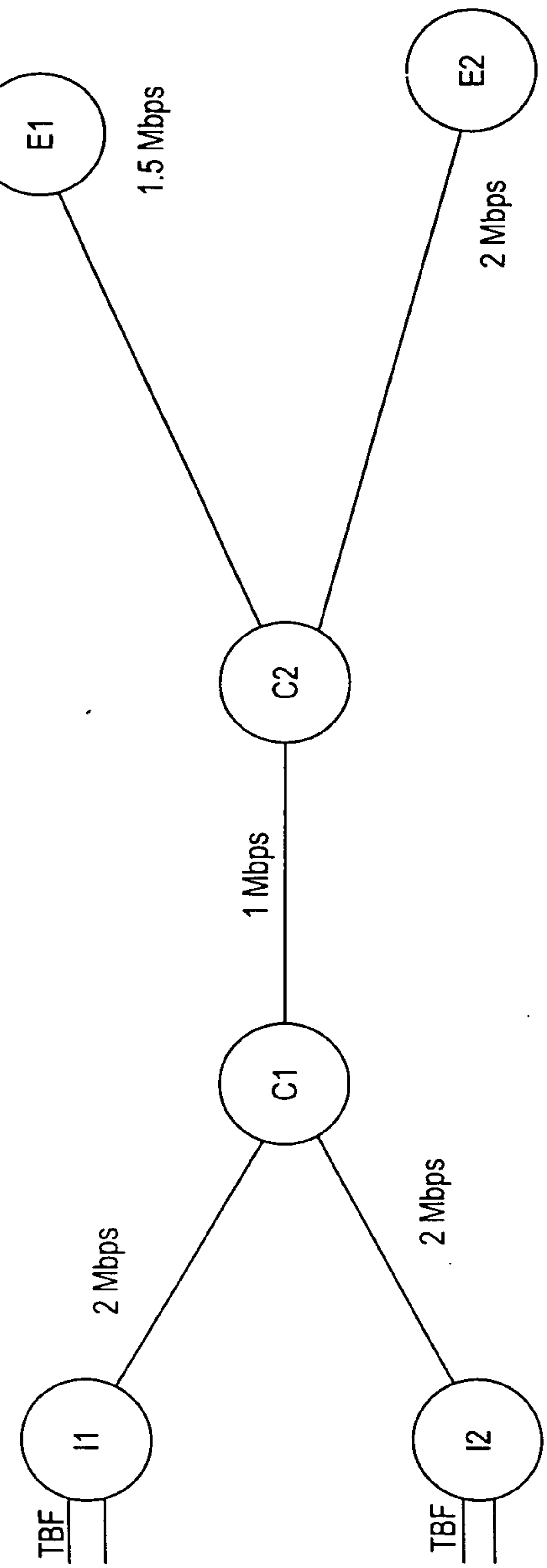
VARYING OF PKT_WT WITH DEMAND AND LCN MESSAGES

FIG. 7



STATE DIAGRAM OF PKTWT DYNAMICS

FIG. 8



THE SIMULATION SETUP
FIG. 9

	NON FEEDBACK SCHEME RED (CORE), % Pkt LOSS	DCM SCHEME % OF PACKET LOSS			
UTIL-IZATION	AT CORE NODES (X)	AT CORE NODES	AT INGRESS TBFs	OVERALL LOSS CORE+TBFs (Y)	OVERALL IMPROVEMENT WITH DCM (RELATIVE REDUCTION $\frac{(X-Y)}{X}$ IN PKT LOSS)
0.5	3.88	1.0859	1.4889	2.5748	33.76
0.6	8.00	2.1948	2.7775	4.9723	37.87
0.7	11.4	2.8461	3.9036	6.7498	40.79
0.8	12.8	2.8148	4.5384	7.3531	42.55
0.9	14.1	2.7192	6.3322	9.0514	35.81
1.0	16.6	2.6678	7.6945	10.3623	37.59
1.1	18.3	2.9650	10.3028	13.2677	27.54
1.2	19.3	2.8883	11.4976	14.3858	25.49
1.3	20.76	2.8530	12.7693	15.6223	24.75

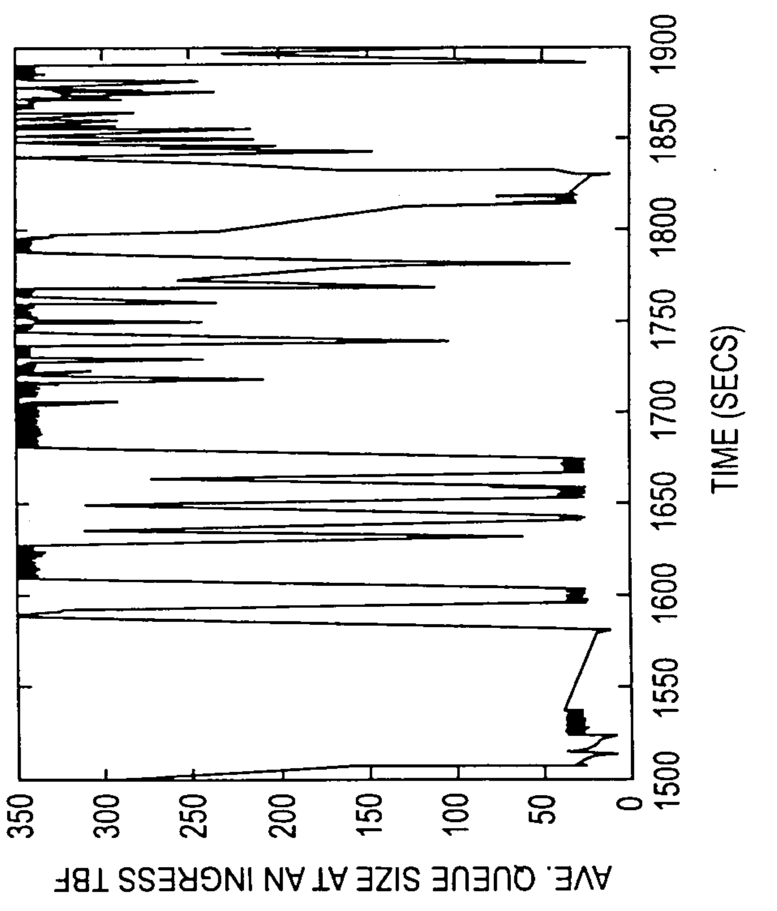
PERFORMANCE OF THE PROPOSED DCM SCHEME

FIG. 10

UTILIZATION	AVERAGE DELAY (SECONDS) AT INGRESS TBFs
0.8	0.771937
0.9	0.924975
1.0	1.007773
1.1	1.273592
1.2	1.339390
1.3	1.389371

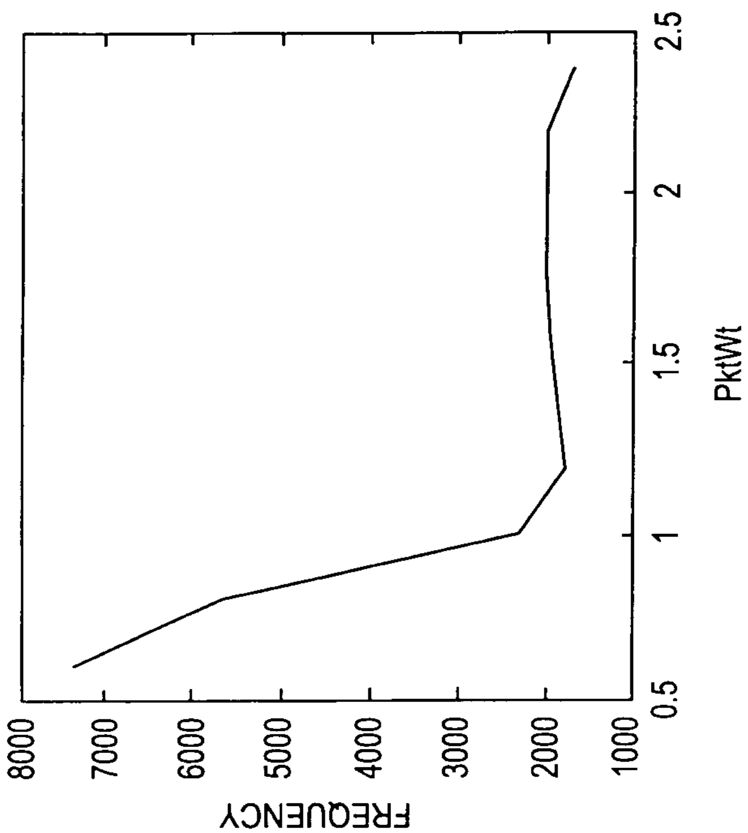
DELAY PERFORMANCE OF THE DCM SCHEME

FIG. 11



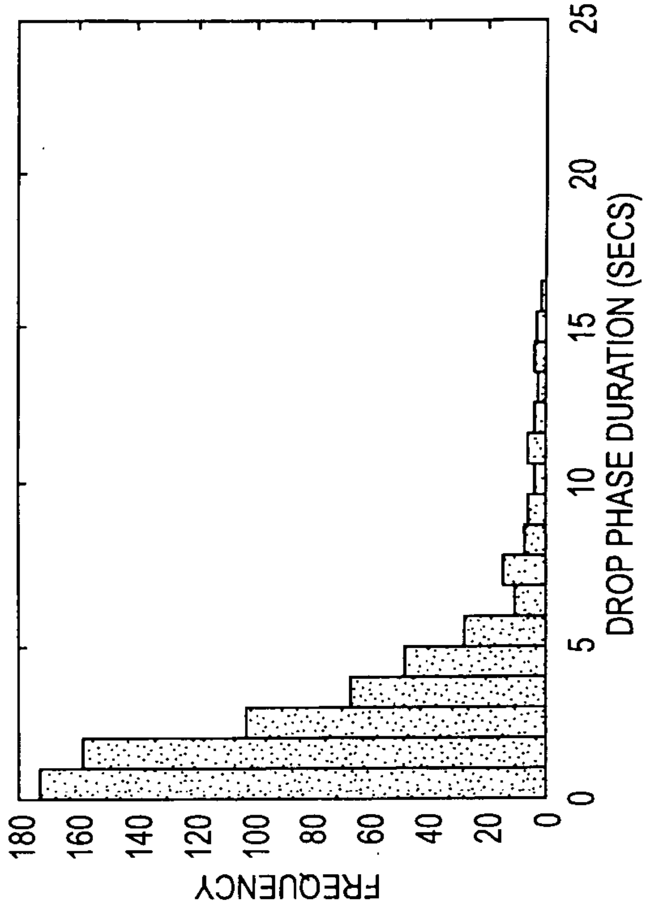
AVE. QUEUE SIZE AT AN INGRESS NODE

FIG. 12A



PKTWT DISTRIBUTION ; UTIL. = 0.8

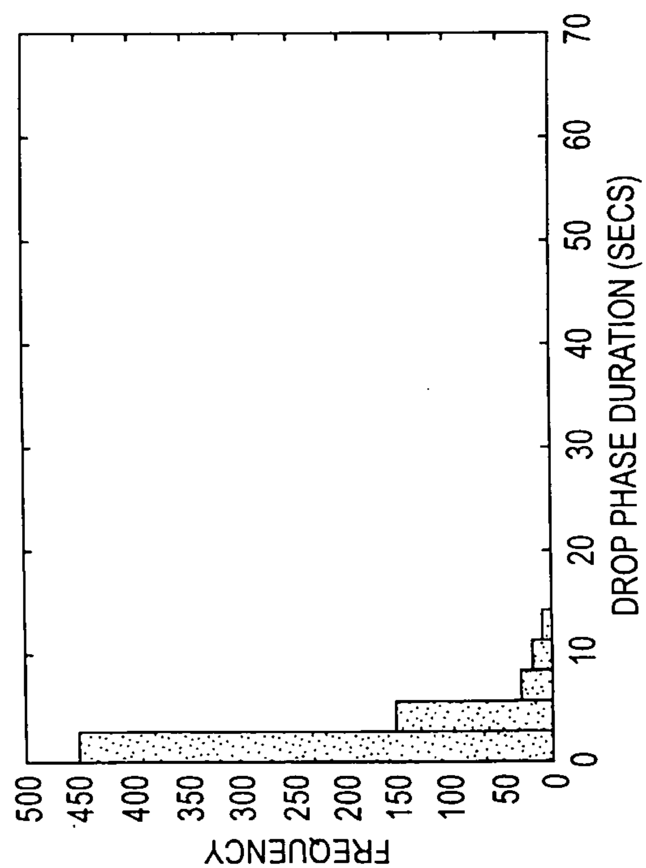
FIG. 12B



NON-DCM SCHEME AT UTILIZATION = 0.9

DISTRIBUTION OF PACKET DROP PHASE DURATION AT THE CORE NODES WITH NON-DCM SCHEME

FIG. 13B



NON-DCM SCHEME AT UTILIZATION = 0.8;

DISTRIBUTION OF PACKET DROP PHASE DURATION AT THE CORE NODES WITH NON-DCM SCHEME

FIG. 13A

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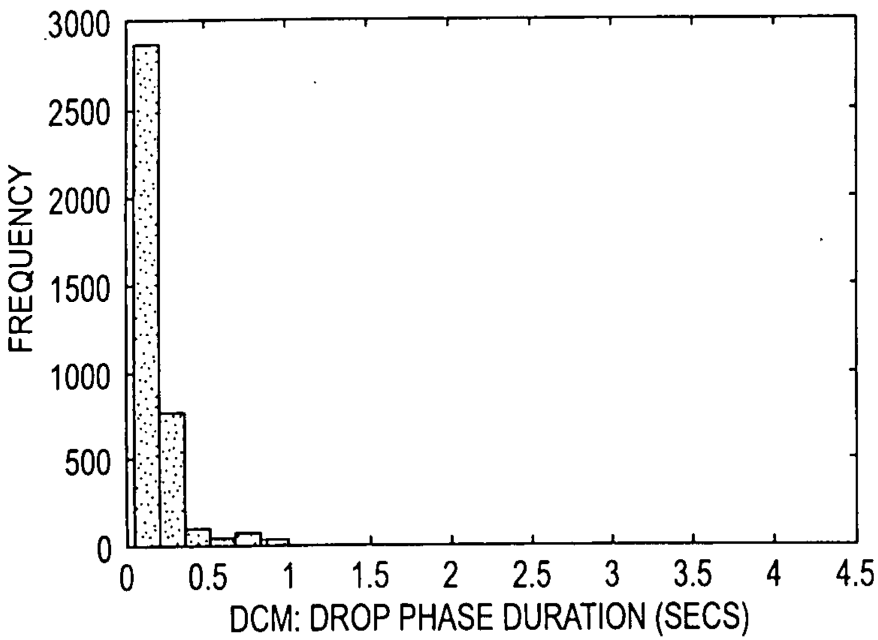
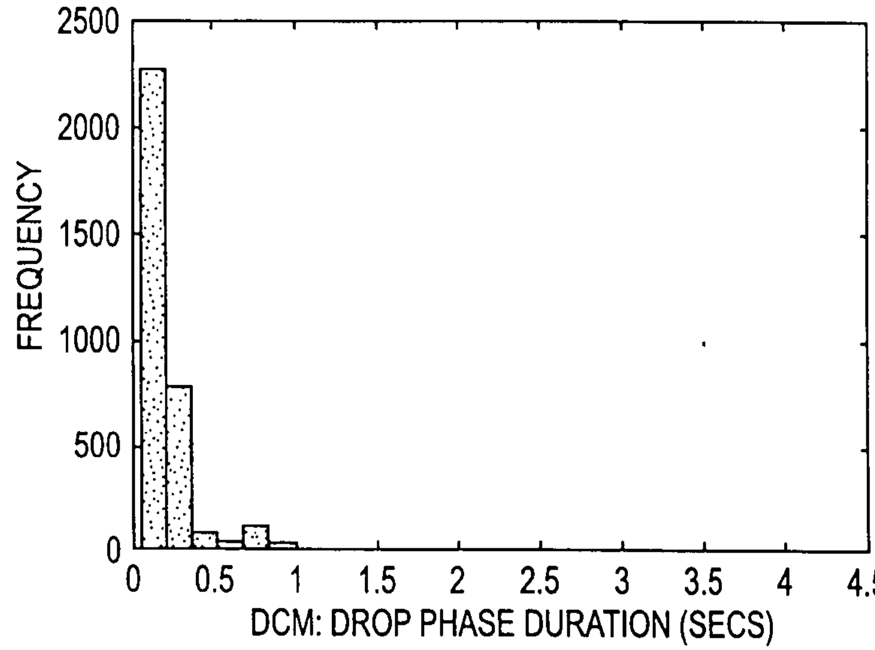


DCM SCHEME AT UTILIZATION = 0.8;

DISTRIBUTION OF PACKET DROP PHASE
DURATION AT THE CORE NODES
WITH DCM SCHEME

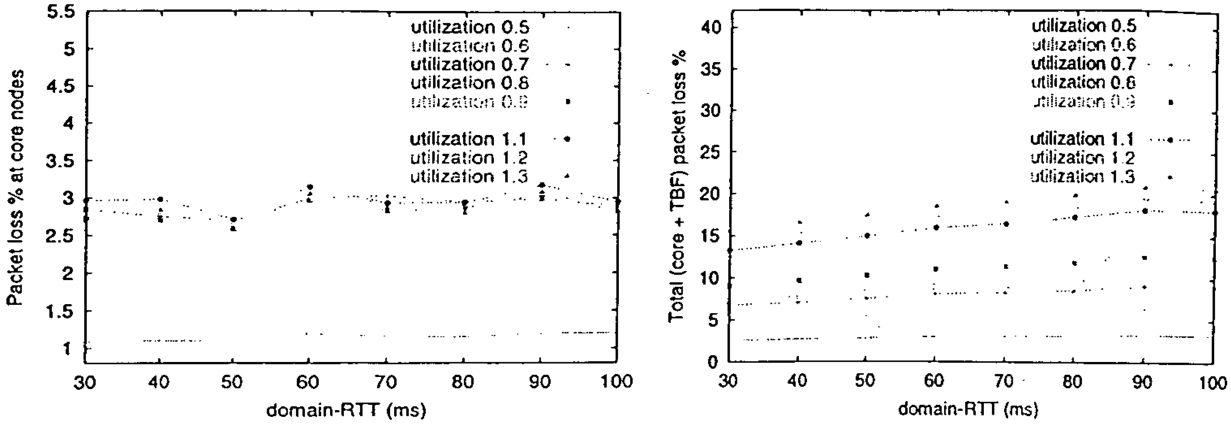
FIG. 14A



DCM SCHEME AT UTILIZATION = 0.9

DISTRIBUTION OF PACKET DROP PHASE
DURATION AT THE CORE NODES
WITH DCM SCHEME

FIG. 14B



(a) packet loss % at core nodes; (b) Total packet loss in the system (core +TBF)

Fig. 15

PERFORMANCE OF THE DCM SCHEME WITH DOMAIN-RTT VARIATION